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ABSTRACT

This study examines why the relational concepts of left and right are more difficult to learn than other relational concepts. A total of 72 children from kindergarten, third grade, and sixth grade, and an additional 24 college students were tested individually on a set of six realistic pictures. The task was to reconstruct the depicted scenes on a flannelboard using reversible felt pieces that were asymmetrical left to right. Three instruction conditions were used: copying, rotation, and perspective or self-rotation. The type and number of errors in orienting the felt pieces were recorded. It was found that errors declined with increasing age. Subjects were found to make more left-right than top-bottom orientation errors, particularly in the younger age range and in the more difficult rotation and perspective conditions. It is suggested that the systematic nature of left-right errors at all ages is consistent with a hypothesis that biological factors contribute to greater difficulty in learning left-right than top-bottom. (GO)

Mental Picture Inversion: Left-right Confusion and Mirror-Imaging in Children and Adults[1]

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In his work on the growth of reasoning, Piaget (1928) suggested that children go through three stages in learning the relational concepts of left and right, finally mastering the notion that they are relative terms, and not absolute spatial locations, around 12 years of age. From this and other work, Piaget concluded that it is not until this age, the beginning of formal operational thought, that children understand relative concepts in general. However, other researchers (e.g., Benton, 1959; Harris, 1972) have found that children learn the relative concepts of up-down and front-back during the pre-school years. In his work, Harris concluded that although understanding the relative nature of left and right is an appreciation of the logic of relations, the difficulty in learning left-right is not just logical -- not the result of an imperfect understanding of relations in general--but is instead specific to these directions. Children simply have more trouble discriminating left from right than top from bottom or front from back.

This greater difficulty with left-right than the other directional dimensions is so common, even in adulthood, as to be taken for granted. This, and the work with children just mentioned, suggests that although relational concepts can be grasped by children earlier than twelve years, there must be something "different" about left and right that make these directions so much more difficult to learn than others.

Why are left and right so hard to learn? Two major types of explanations have been suggested. One is that there are fewer intrinsic left-right cues in objects than there are cues for the other directions. Even the left-right cues that are present in objects are generally less operationally salient than top-bottom or front-back cues.

This can be considered an 'environmental' explanation. With respect to the Three Mountains Test, Piaget (1956) suggested that front and back are easier to learn than left and right because they are at different distances from the subject and therefore require different actions from him, while left and right are equidistant and evoke very similar actions. This argument, however, falls short in explaining why top and bottom are easier to learn, because top and bottom are as often equidistant from the child as are left and right. So environmental, experiential factors don't seem to fully explain the difficulty with left and right. Corballis and Beale (1970) have posited a biological reason -- that the human nervous system (and that of all bilaterally symmetrical animals) is wired to favor recognition of top-bottom cues more than left-right, because of greater top-bottom than left-right asymmetry of the body and nervous system.

Most likely the reasons for the difficulty are both environmental and biological. If left-right relations are difficult simply because of environmental and experiential factors, but mastered by twelve years, we would expect few left-right errors in adults. And we would expect errors that we <u>did</u> find to be haphazard, as though stemming from the individual's failure to note left-right distinctions because of their low availability and low saliency. We would also expect left-right errors to increase in situations with which the subject has had relatively little experience.

However, if we are <u>constitutionally</u> predisposed to confuse left-right, those left-right errors that persist into adulthood should be systematic, not haphazard.

The type of left-right error most likely to persist is the mirror-image error. Children confuse left-right mirror-image designs more often than equivalent top-bottom mirror-images. And even past eleven years of age, they will mirror rather than transpose when asked to copy the gestures of someone facing them (for example, they will touch their right leg when the experimenter facing them touches his left, as though looking in a mirror). This mirroring tendency weakens with age, but is still evident in adults when gesture imitation is elicited unobtrusively by simply telling someone "You've got something on your face" while pointing to either side of one's own face. One purpose of the present study was to test whether mirror-imaging persists into adulthood, as a result of a constitutional disposition for confusing left and right.

If, as suggested, left-right difficulty has both environmental and biological roots several predictions follow as to the nature of errors made in a test requiring operations in the left-right and top-bottom dimensions. People will make more left-right than top-bottom errors, at all ages. These errors will be systematic rather than haphazard. There would be fewer errors, particularly top-bottom, in situations with which the subject is familiar, than in situations with which he has had less experience. Developmentally these predictions should be borne out most strongly in young children. And though errors should decrease with age, as subjects gain in experience and in the ability to inhibit natural tendencies to mirror, when young adults do err, even they will make more left-right than top-bottom errors. These errors will be of a systematic type, probably mirroring errors.

METHODS:

I designed a picture reconstruction task to test these predictions. Seventy-two children were tested individually -- 12 boys and 12 girls in each of the following age groups: kindergarten, 3rd grade and 6th grade. I chose these ages because they are presumably the pivotal ages for the three stages of learning left-right. Twenty-four college students -- 12 men and 12 women -- were also tested since they should have no trouble with left-right, according to Piaget's scheme.

Each subject was shown each of six 9"x 12" pictures of realistic scenes (see Fig. 1) and asked to reconstruct them on a flannelboard with reversible felt pieces, one at a time, according to six instruction situations varying in difficulty (which I will describe in a moment).

Figure 1 here

Each of the standards had four corresponding felt pieces, which were designed so as to have visually obvious left-right as well as top-bottom orientation cues. Referring to examples in Fig. 1, the picture in the upper left-hand corner shows: 1) a house, with 2) a separate door, 3) a lopsided bush, and 4) a moon-with-star-attached. Since it may be unclear, the middle picture on the bottom shows 1) a TV dinner, 2) separate piece of chicken (with a bite in it to make it asymmetrical), 3) fork-with-napkin, and 4) flowers. All pieces were asymmetrical left to right and top to bottom. Although in some cases the pieces represented 3-dimensional symmetrical objects (e.g., the chair and table in the middle picture, top of Fig. 1), they were made to be asymmetrical in a 2-dimensional representation (viewed from off-center).

For each of the six reconstructions, a different one of the standards was attached to a large posterboard hung on a wall. The subject stood at an easel 3½ feet from this display and reconstructed his flannel-board picture with the corresponding felt pieces. The standard was left in position for the subject to refer to while he made his reconstruction.

The three instruction conditions used were 1) copy, 2) rotation, and 3) perspective. In the copy condition, the subject was instructed to "make a picture exactly the way" the standard was shown. In the rotation condition, the instructions were "to make a picture to show how" the standard would look to the subject if it -- the picture -- were turned upside-down. The instructions for the perspective condition were "to make a picture to show how" the standard would look to the subject if he were upside-down (this is referred to as "perspective condition" in the figures, but could also be called self-rotation). In the last two conditions the subject was told not to try to turn his head upside-down while looking at the standard, and not to simply copy the standard and then turn his copy upside-down (although, interestingly enough, these possibilities did not occur to most subjects). They had to perform the operations "all in their heads". All Ss received all instructions, with order of the last two conditions counterbalanced within age and sex.

For each condition the subjects had to reconstruct two pictures, for a grand total of six. For the first reconstruction in each condition, the standard was presented right-side-up. For the second reconstruction, the standard was presented upside down.

Most people have had much experience copying, but probably much less experience working with objects that must be rotated, and the least

amount of experience being upside-down themselves while looking at things. So if experience is the critical factor, the copy condition should be easiest, the rotation condition somewhat harder, and the perspective condition hardest of all. There is already evidence supporting part of this prediction. Huttenlocher & Presson (1974) found that 3rd and 5th graders do make more errors in predicting the effects of a perspective change on the spatial relationships among objects in an array than in predicting the effects of rotating the array, although the two operations produce the same retinal image.

Finally, because people have much more experience with right-side-up things than with upside-down, I predicted that within each instruction condition, reconstructing a picture presented upside-down would be more difficult than reconstructing a picture presented right-side-up.

Because the felt pieces were reversible, errors in left-right orientation could be made independently of errors in top-bottom orientation for each piece. Left-right and top-bottom orientation errors were scored separately for the four felt pieces in each reconstruction, and an analysis of variance was performed on these scores for the following factors: 2 genders, 4 ages, 3 conditions, 2 presentation modes (upside-down, and right-side-up), and 2 orientation error types (left-right and top-bottom).

As predicted, errors decline with age when summed across gender, conditions, presentation modes, and type of orientation error (see Figure 2).

Figure 2 here

The total possible number of either type of error in one picture was four, with chance performance equaling two. Figure 3 shows that, summed over other factors, the least number of errors was made in the copy condition, the most in the perspective condition, with number of errors in the rotation condition falling between these two -- again as predicted.

Figure 3 here

In Figure 4 we see that the subjects made more orientation errors in reconstructions when the standard was presented to them upside-down than when the standard was presented right-side-up.

Figure 4 here

This was a small but significant difference. This presentation effect -- as we see in Figure 5 -- holds for 3rd and 6th graders most strongly.

Figure 5 here

The effect is weak in college students and even weaker in kindergarteners.

As you can see in Figure 5 , and as we know from the age effect, kindergarteners do worst overall, erring about 50% of the time in orienting their felt pieces (chance level). They found both presentations equally difficult, while college students, who made few errors, found them about equally easy. Perhaps differences in amounts of experience with situations reflected in the conditions of the test can account for these age differences.

Summed across other variables, subjects made more left-right than top-bottom orientation errors (see Figure 6).

Figure 6 here

Subjects made their felt pieces face left when they should have faced right (or vice versa) more often than they had them facing up when they should have been facing down. This was most characteristic of the children and only a tendency appeared in the college students (see Figure 7), probably because they made few errors overall (approximately 10%).

Figure 7 here

The higher frequency of left-right than top-bottom errors was also more pronounced in the more difficult tasks requiring mental inversion -- rotation and perspective conditions -- than in the copy condition, which produced few errors of either type (see Figure 8).

Figure 8 here

This pattern held true within each age group (although of course the mean number of errors differed between age groups).

The results of this analysis of orientation errors support the general predictions about left-right and top-bottom errors, age differences, and condition difficulty that were generated primarily from the environmental explanation for left-right difficulty. But it does not clearly indicate what the overall configurations of the reconstructions looked like, and what kinds of left-right errors were made.

Earlier I suggested that if humans are constitutionally predisposed to confuse left and right, most errors that even adults would make would not be haphazard, as though they simply had not noticed left-right distinctions, but instead would follow some sort of system such as a mirroring type of solution. Figure 9 shows the scheme devised for categorizing the subjects' solutions (reconstructions) according to their overall configurations.

Figure 9 here

At the top of the figure is one of the six standards used in the study. Below it are examples of the four categories for scoring the subjects' reconstructions. Only the reconstructions for the rotation and perspective conditions were categorized and analyzed according to this scheme. To refresh your memory, in the rotation condition the subject was shown a standard such as the one on the top of the slide and asked to predict how the standard would look if it were upside-down. In the perspective condition he was asked to predict how the standard would look to him if he were upside-down. The four scoring categories are, from left to right: correct solution, in which the subject has correctly rotated both the left-right and the top-bottom dimensions; mirror solution, an incorrect solution in which the subject has rotated only the top-bottom dimension and "mirrored" the left-right dimension from the standard (this effect can't be produced by rotating the standard, but looks the way the standard would look if we held a mirror at a 90° angle away from its bottom edge, and represents a systematic type of left-right error).

The next solution category shown is the copy, which is a systematic but incorrect solution for the rotation and perspective conditions. (Recall that these are the only conditions analyzed this way. Don't confuse the copy solution here with the copy condition, in which a copy would have obviously been a correct solution.) Finally we have an example of one miscellaneous solution -- the category containing all pictures that did not fit in the other three categories. In this last category, the errors made are haphazard and unsystematic. The examples of the scoring categories here are idealized -- in any given reconstruction, the overall configuration was important, although a single felt piece may have been improperly positioned or oriented in the wrong direction.

With regard to the pictures thus categorized, we now can ask, "How are these solution types distributed within each age group?" Figure 10 shows frequency histograms of these solution types for the four age groups, combining the rotation and perspective conditions.

Figure 10 here

As you can see, differences in frequency distributions among the four age groups are due mainly to the fact that frequency of correct solutions increase steadily with age. However, we can also look at the distributions of the remaining incorrect solution types for each age to see whether incorrect solutions are of a systematic nature (mirror-inversion or copy), which would suggest that biological factors affect left-right difficulty, or whether they are haphazard (miscellaneous), indicating mainly environmental causes.

When we look at this in Figure 10 we find that, in <u>all</u> age groups, the <u>most</u> frequent type of <u>incorrect</u> solution is mirror-inversion, the second most frequent is copy, and the <u>least</u> frequent is miscellaneous.

Thus we can see that the left-right errors that occur in a mental picture inversion task are usually of a systematic nature at all ages, being primarily mirror-inversions. Unsystematic, haphazard left-right errors occur infrequently. The systematic nature of left-right errors at all ages is consistent with a hypothesis that biological factors contribute to the greater difficulty in learning left-right than top-bottom. The most obvious of these biological factors is the relative left-right symmetry and top-bottom asymmetry of the nervous system. The effects of biological factors in the learning of left-right and top-bottom are modified by experience inasmuch as errors overall decrease with age (although left-right errors are always more frequent than top-bottom errors) and are directly proportional to task difficulty.

-Footnote-

[1] This research report is based on an M.A. thesis submitted to the Department of Psychology, Michigan State University, 1975.

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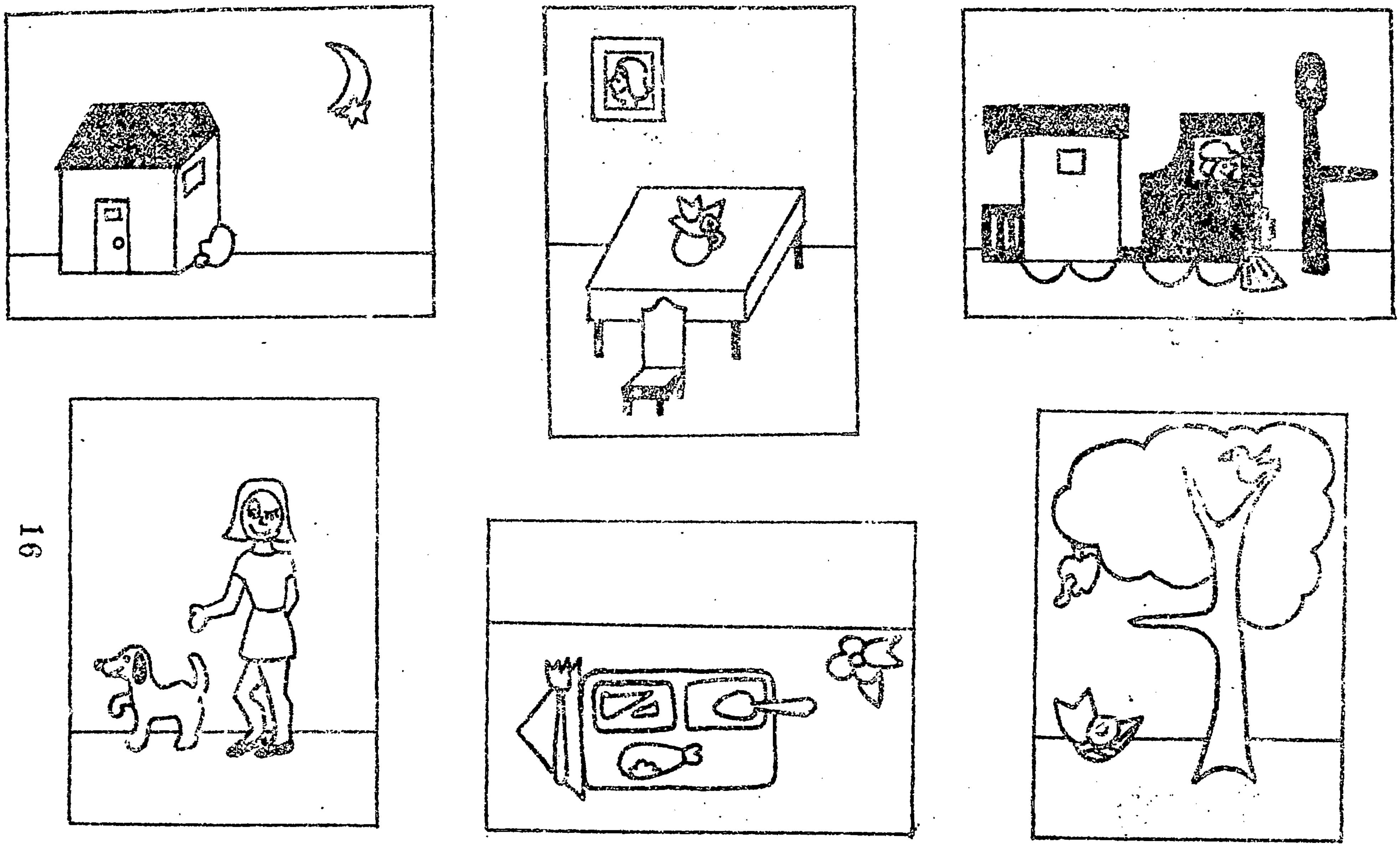


Figure 1. Six picture standards shown to each subject.

Figure 2. Mean number of orientation errors (either type) per picture for each age group, and results of main effect for age from analysis of variance.

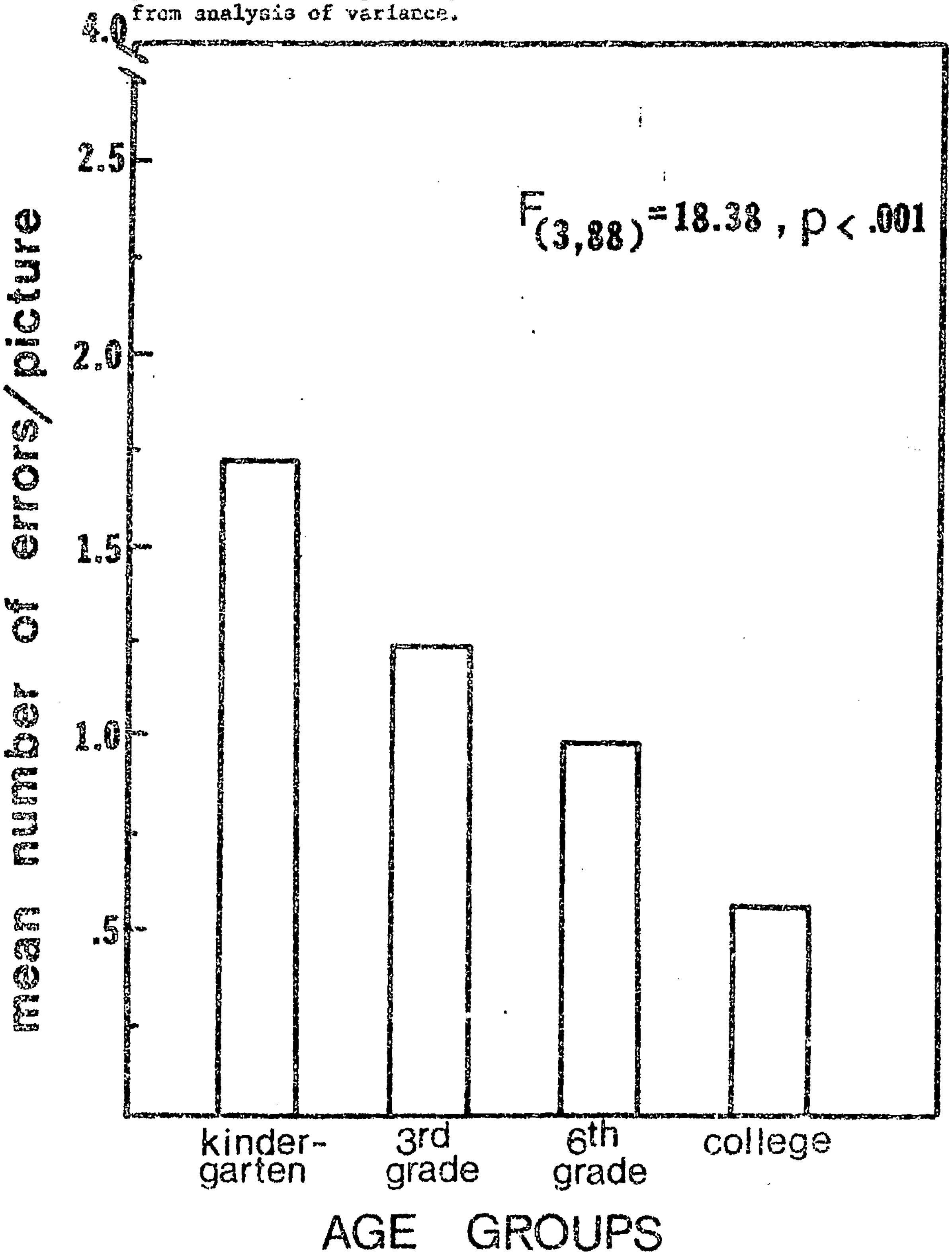


Figure 3. Mean number of orientation errors (either type) per picture within each condition, summed across other factors, and results of main effect for condition from analysis of variance.

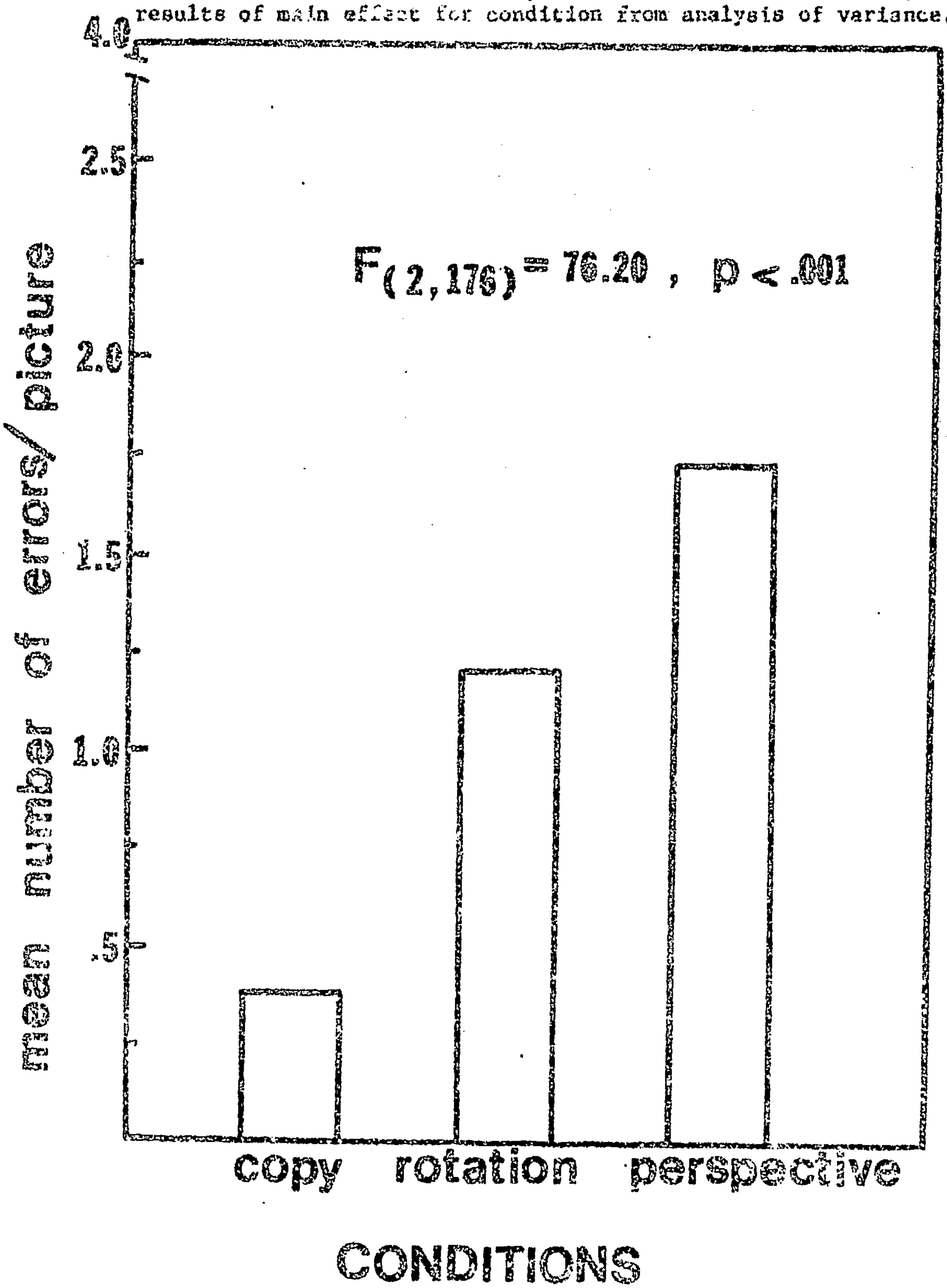


Figure 4. Mean number of orientation errors (either type) per picture within each presentation mode (upside-down, right-side-up) of the standards, summed across other factors, and results of main effect for presentation mode from analysis of variance.

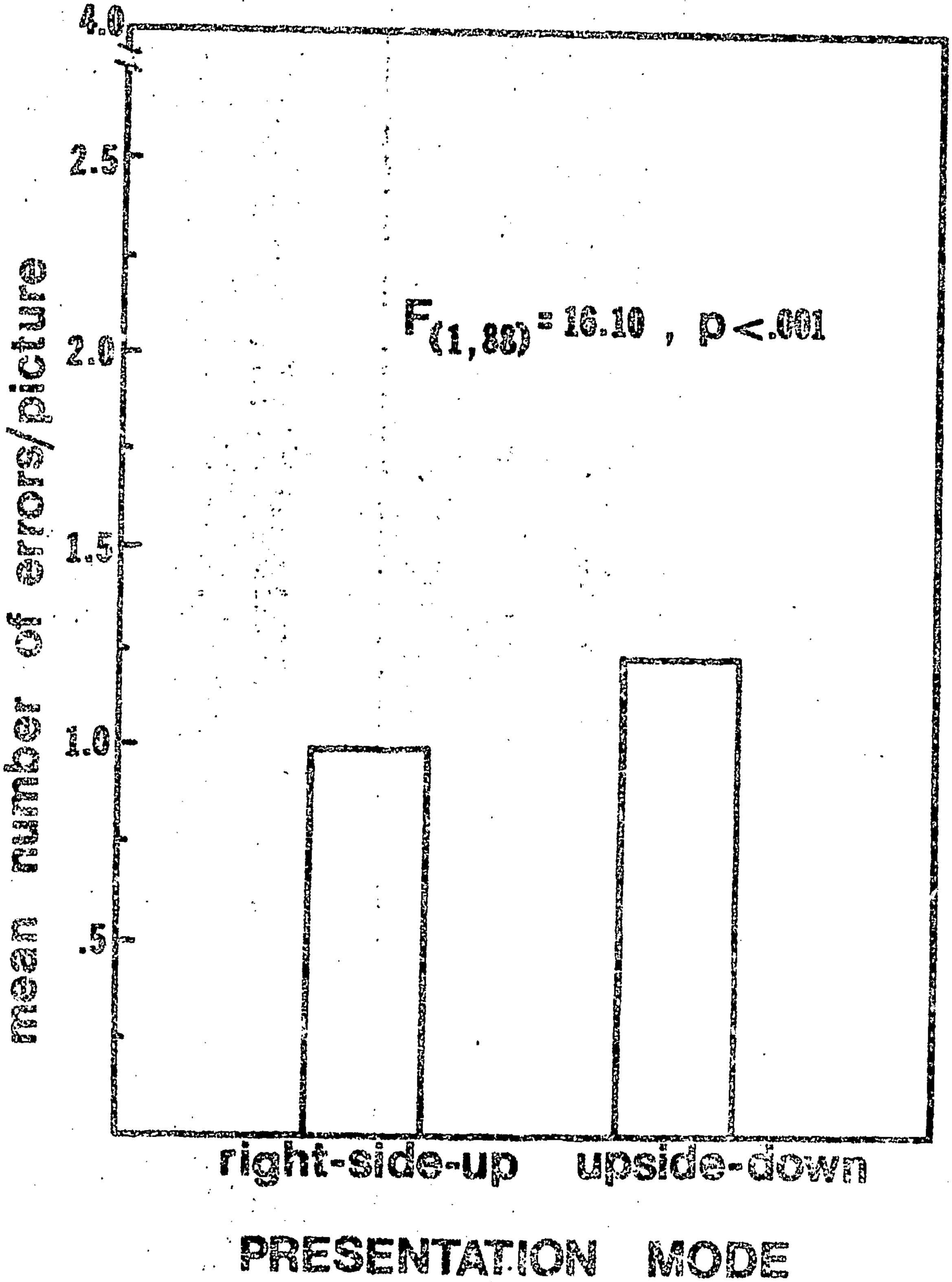


Figure 5. Mean number of orientation errors (either type) per picture within each age group for both presentation modes, and results of age x presentation mode interaction from analysis of variance.

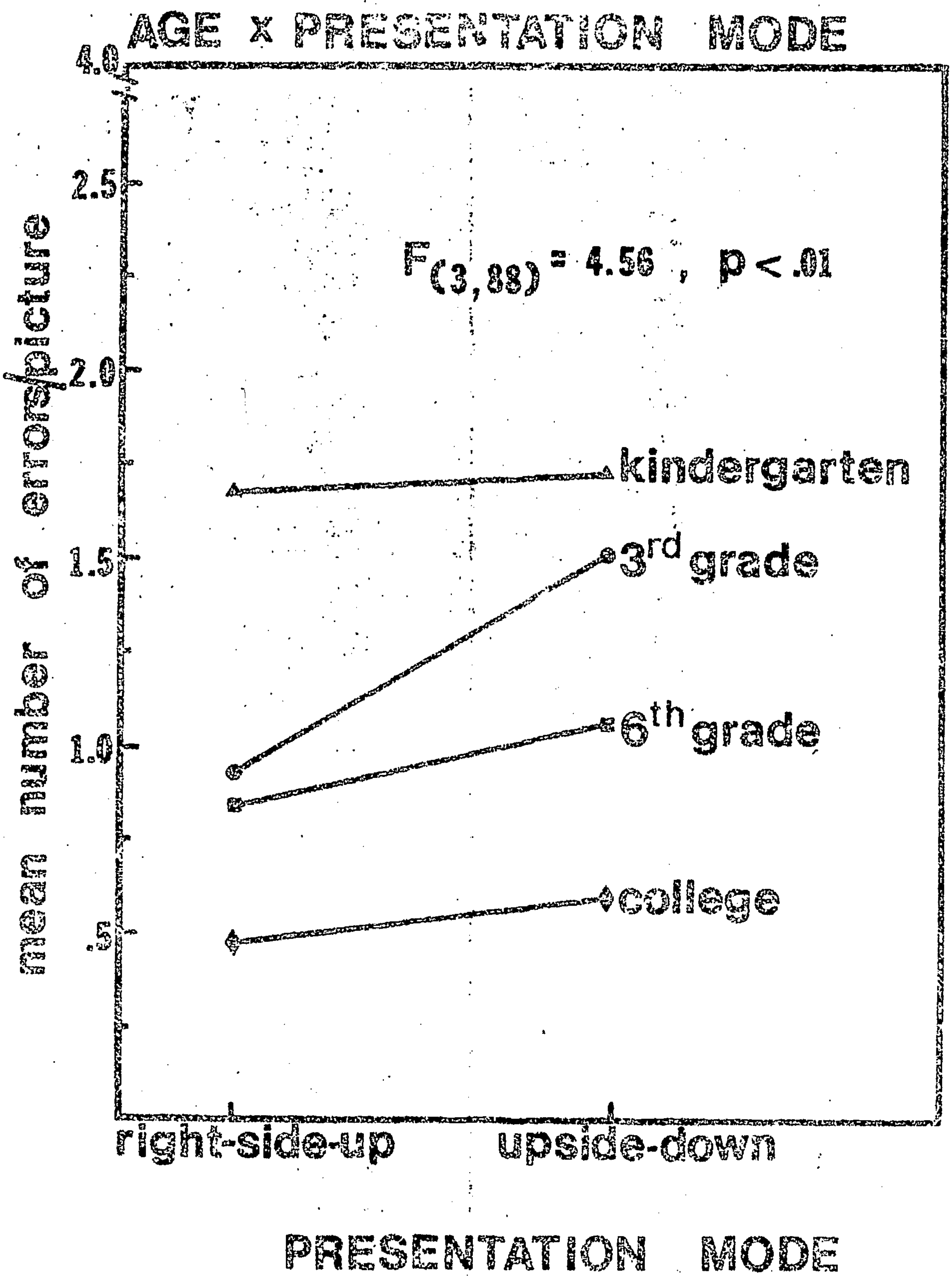


Figure 6. Mean number of orientation errors (either type) per picture for the two types of orientation errors, and results of main effect for orientation error type from analysis of variance.

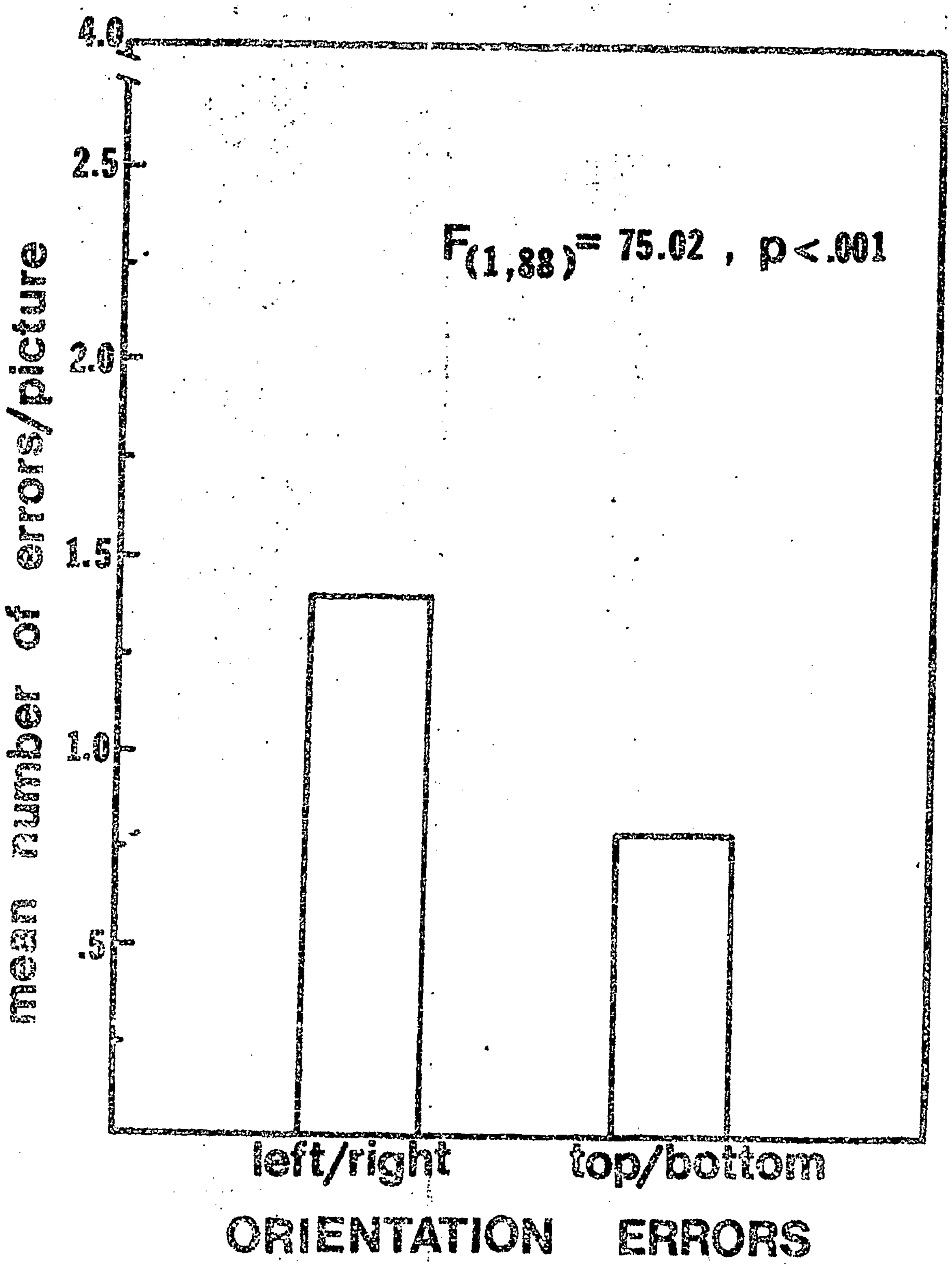


Figure 7. Mean number of orientation errors (either type) per picture within each age group for the two types of orientation errors, and results for age x orientation type from analysis of variance.

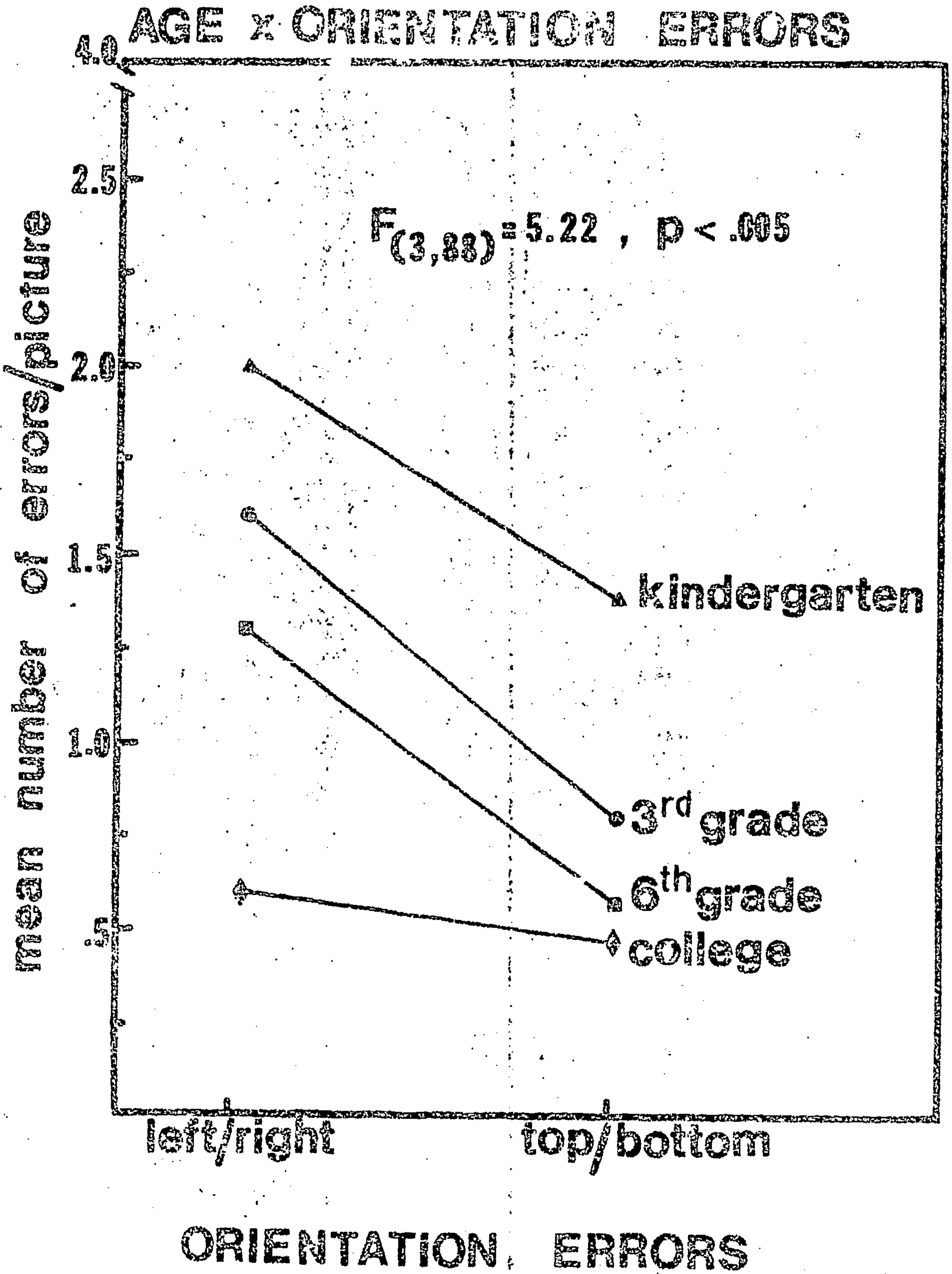


Figure 8. Mean number of orientation errors (either type) per picture for the two types of orientation errors within each condition, and results for condition x orientation error interaction from the analysis of variance.

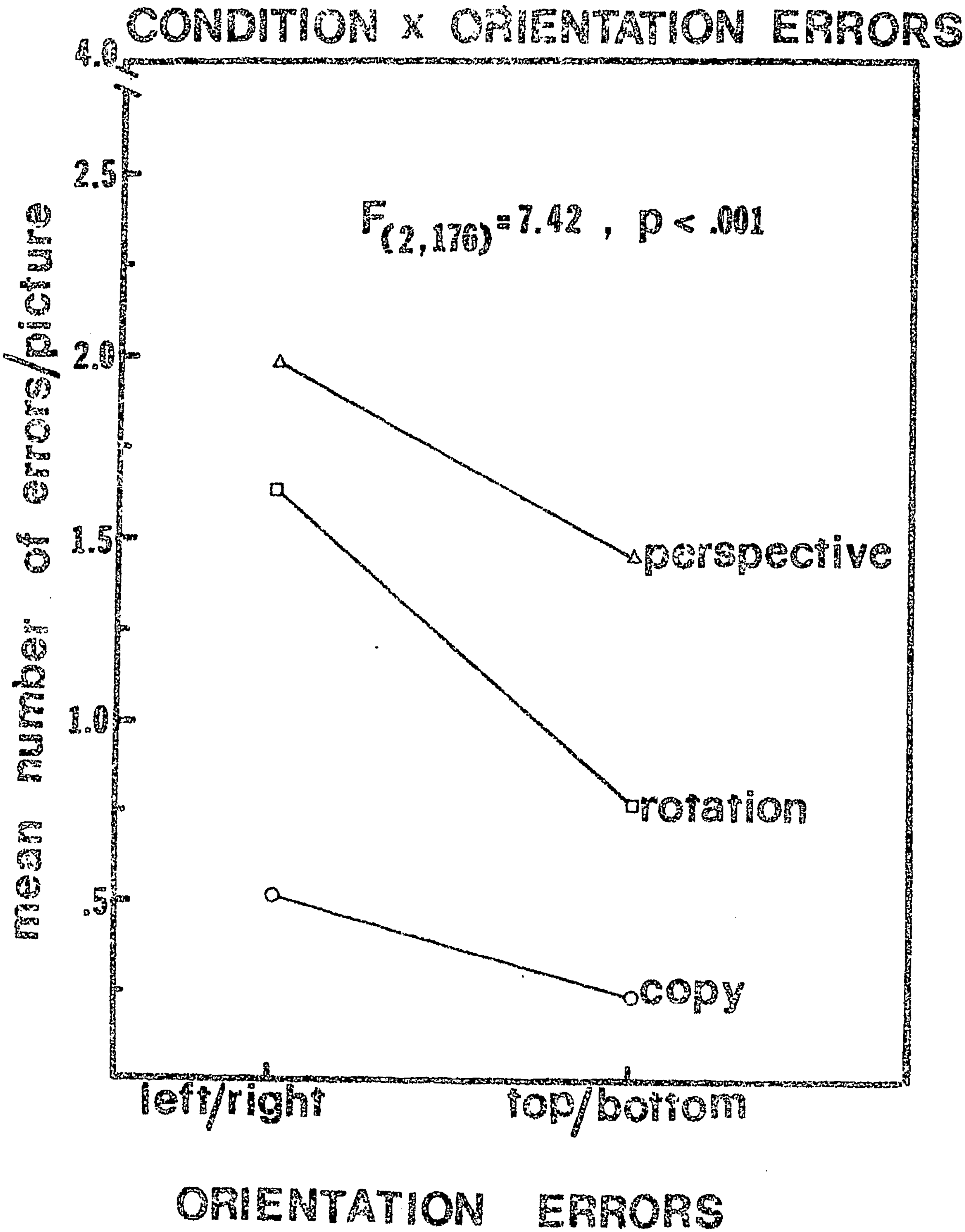
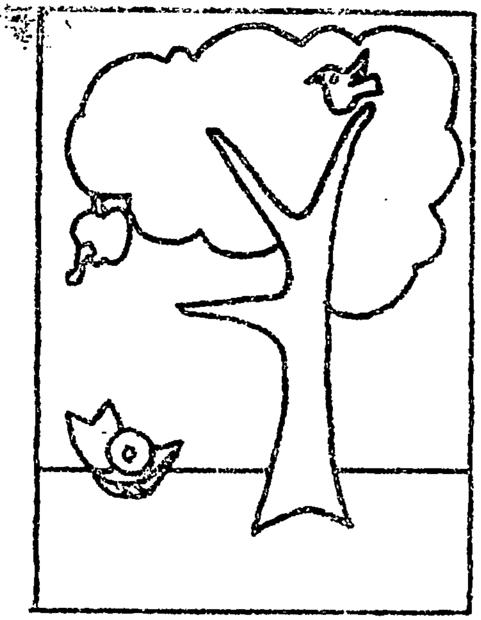
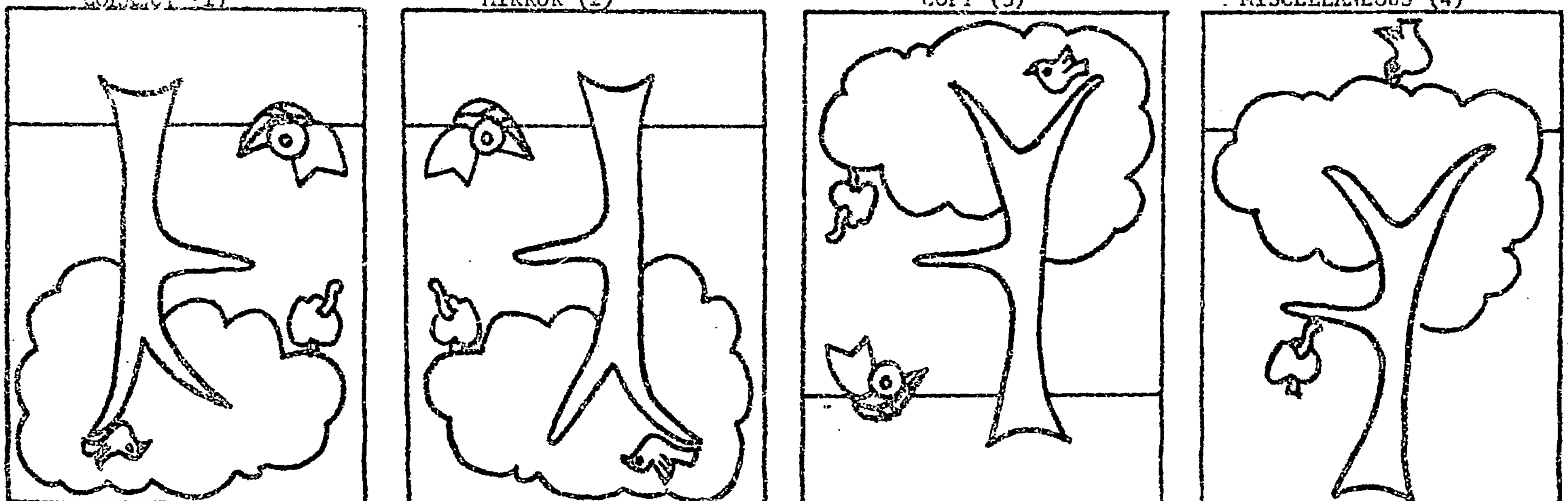


Figure 9. The four scoring categories for subjects' solutions to the rotation and perspective instruction conditions. MIRROR, COPY AND MISCELLANEOUS are considered incorrect solutions. The picture at the top here is an example of the picture standards shown to the subject.



Standard Picture

CORRECT (1) MIRROR (2) COPY (3) MISCELLANEOUS (4)



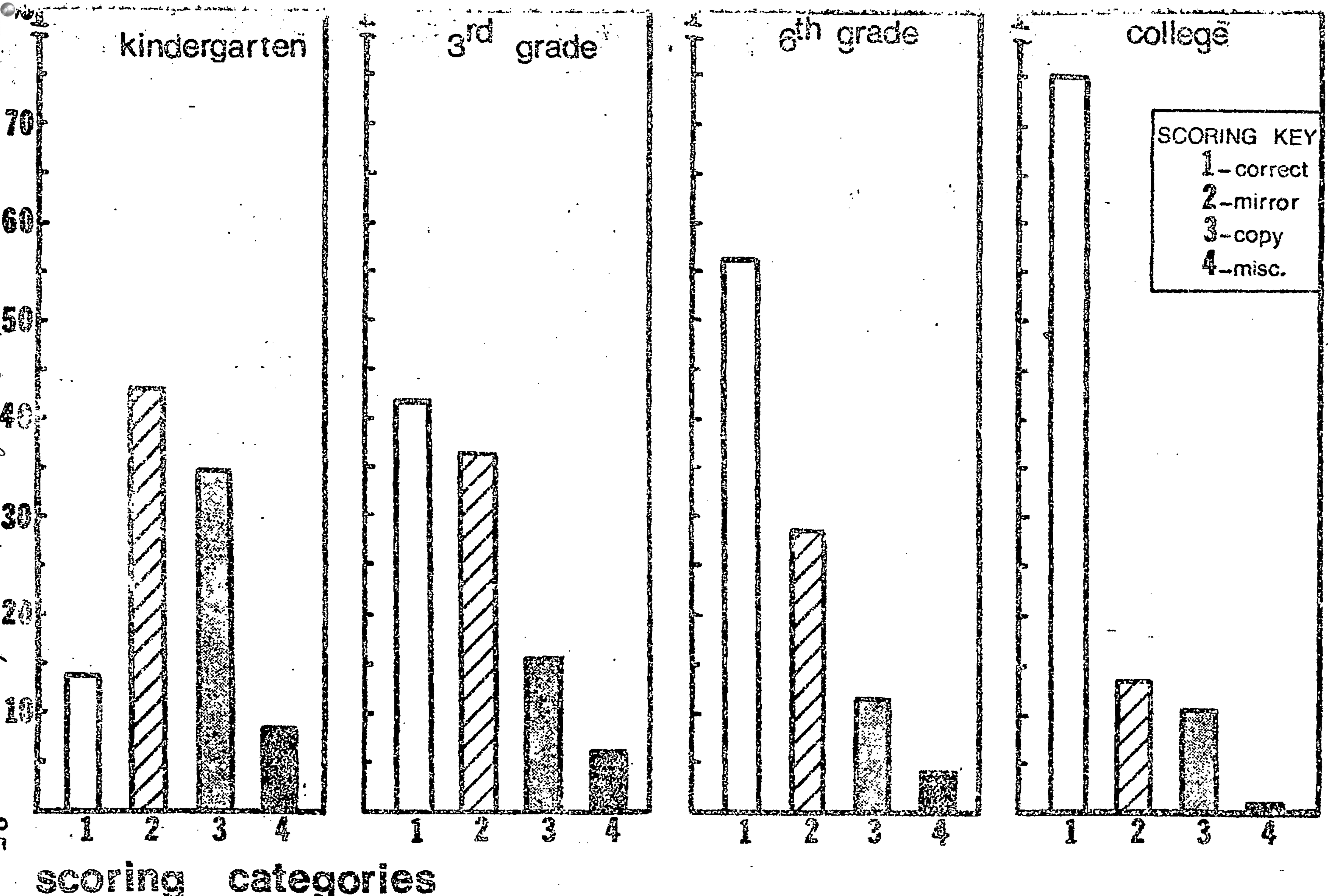


Figure 10. Frequency distributions of the four solution categories for pictures in the rotation and perspective conditions within each age group.